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SURFACE WATER MONITORING SYSTEM INSTALLED ON BOARD THE ICEBREAKER SHIRASE

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Abstract: A surface water monitoring system was designed and installed on board the icebreaker SHIRASE. The system consists of sensors unit, navigation information terminal and control unit. Water pumped up from an intake of hull (8 m depth) is led into the sensors unit so as to measure flow rate of water, water temperature, conductivity, dissolved oxygen, fluorescence intensity, size composition of plankton and concentration of nutrient salt. Analog signals from these sensors as well as digital data from navigation information terminal (GMT, position, ship's speed, sea depth, water and air temperature) are transferred into the control unit at intervals of every five minutes. All data are stored on a floppy disk mounted in the control unit simultaneously. A post data processing enables data editing, graphic displaying of time series data and geographical mapping. A field experiment in JARE-27 (1985/86) to the Antarctic Ocean revealed the usefulness of the present system for detecting fine-micro scale temporal and spatial variations of phytoplankton in relation to the oceanographic variables.

1. Introduction

Since the 1965/66 austral summer, concentration of the surface water chlorophyll *a* has been measured routinely on board the Japanese icebreaker FUJI 2-3 times a day by bucket sampling along the cruise track (HOSHIAI, 1968). From these annual observations, the important information on the geographic variations of phytoplankton standing stocks and their seasonal periodicities in the Indian sector of the Antarctic Ocean is discussed (FUKUCHI, 1980). The spatial resolutions of these routine observations are very sparse (4-14 h or 50-70 miles intervals). In 1978-79, two hours manual sampling was carried out (FUKUCHI and TAMURA, 1982) to improve the resolution.

Since the 25th Japanese Antarctic Research Expedition (JARE-25) in the 1983/84 summer, a continuous measuring-recording system was firstly designed for the new icebreaker SHIRASE by HAMADA *et al.* (1985). They continuously recorded *in vivo* fluorescence intensity of the flowing water, which was pumped up from an intake on hull (8 m depth), in analog form on a chart paper. Secondarily, FUKUCHI *et al.* (1986) modified the prototype and designed the new computerized system for the cruise of JARE-26 (1984/85). The personal computer was used for a real time data processing (measuring and recording of *in vivo* fluorescence intensity and water temperature) as well as a post data processing. However, a self-priming cascade pump used in the two preceding cruises was set on the floor of No. 5 laboratory about 8 m above sea level.

Thirdly, we designed the system not only to increase the kinds of data items continuously measured as many as six kinds, but also to acquire the navigation information such as GMT, ship's position, etc. Also the post data processing was improved. The present system, a surface water monitoring system, was successfully available for the JARE-27 cruise (1985/86) from November 1985 to April 1986.

This paper describes the instrumentation of the system and presents the first field experiment.

2. Surface Water Monitoring System

A block diagram of the surface water monitoring system is shown in Fig. 1.

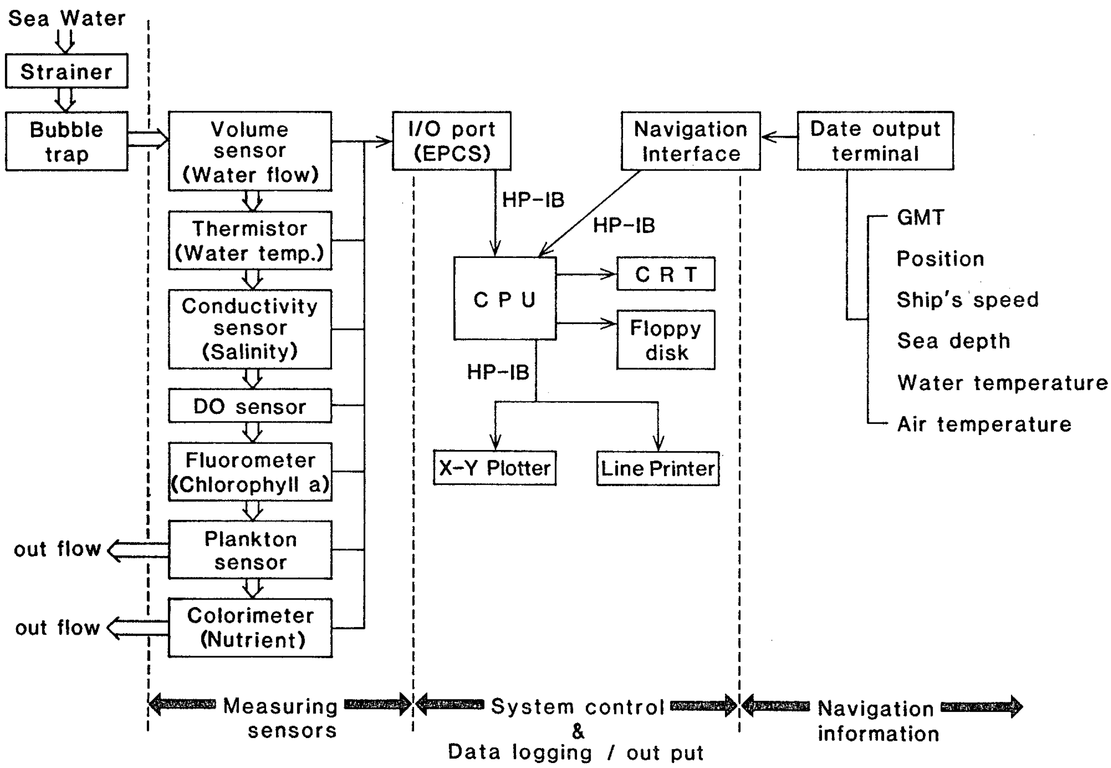

Fig. 1. A block diagram of the surface water monitoring system installed on board the icebreaker SHIRASE.

A one-rotar screw pump (Moineau typed pump, model HNP-201S, Taiko Kikai Co. Ltd.) was installed in the shaft tunnel, about 3 m below sea level. This pump has a capacity of pumping 30 l/min and does not damage zooplankters mechanically.

Sea water pumped up to the laboratory and was led to a strainer and a bubble trap in order to remove large organisms (>5 mm in diameter) and to eliminate air bubbles, respectively. Then, the sea water passed through five kinds of sensors and finally a part of over-flowed water was led to nutrient analysis.

2.1. Measuring items

The rate of water flow was measured by a paddlewheel type flow sensor and six items were measured by sensors listed in Table 1. An electronic plankton counting and sizing system (EPCS) was designed by MACKAS *et al.* (1981), which counts respective particles in the size range of 0.5–5.0 mm equivalent spherical diameter.

All sensors except for nutrient analysis were arranged within the rack as shown in Fig. 2. An auto analyzer for nutrient was set on another table (Fig. 3). Either silicate or nitrogen (nitrate plus nitrite-N) was measured continuously for 7–10 days,

Table 1. Seven measuring items of the surface water monitoring system and characteristics of sensors.

Measuring item	Sensor
Water flow	Paddlewheel flowsensor (model MK 515, Signet Scientific, USA)
Temperature	Pt 100Ω sensor (Honchigo, Japan)
Salinity	4 Electrode Dual Glass (Applied Microsystems, Canada)
DO	Polarograph (model EMCO, Danfoss, Denmark)
Chlorophyll *a*	Field fluorometer model 10-000R (Turner Designs, USA)
Zooplankton	Multiple-orifice four annular electrodes (Meyer Systems, Canada)
Nutrient	Auto Analyzer II (Technicon, USA)

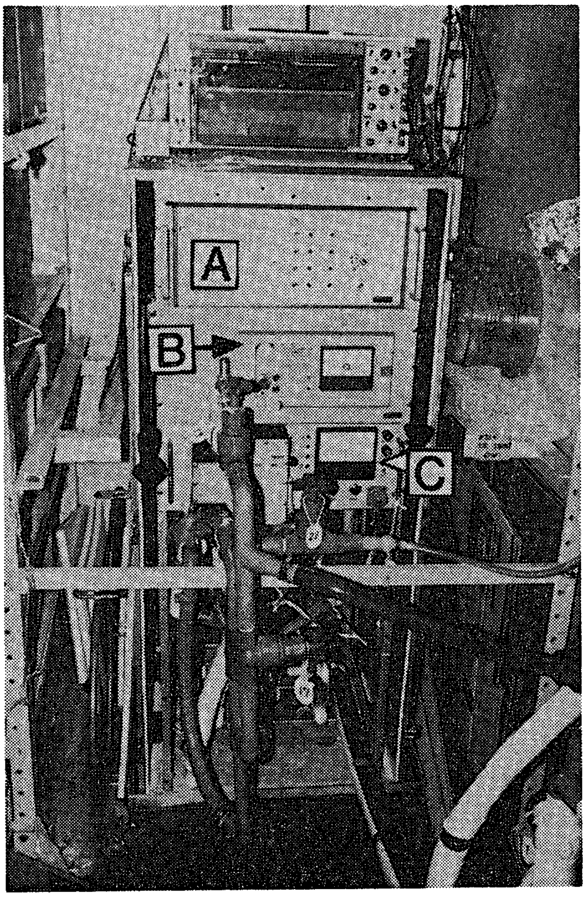

Fig. 2. A rack of measuring sensors of the monitoring system.
A: I/O port (EPCS; Electronic plankton counting and sizing system), B: DO meter, and C: Turner Designs fluorometer.

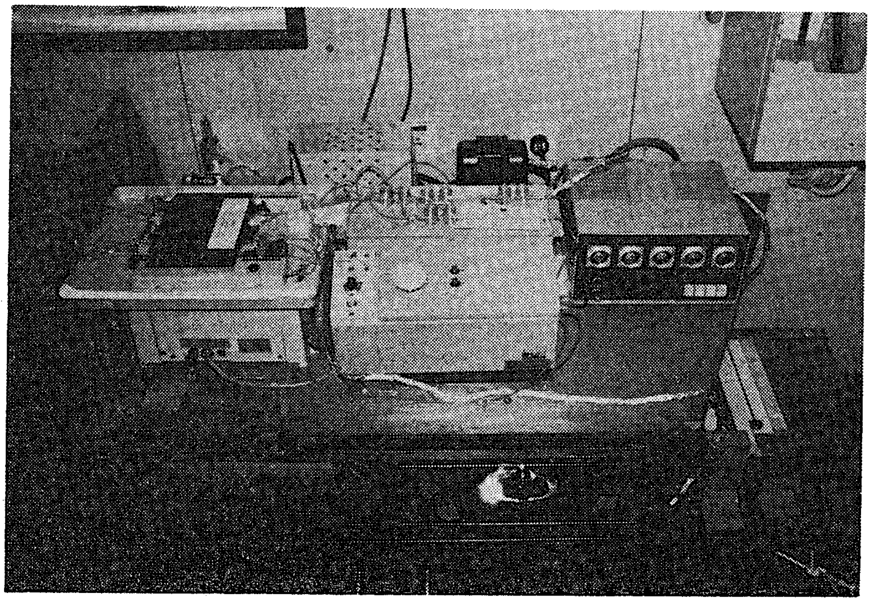

Fig. 3. Technicon Auto Analyzer II. Five timers are seen in the right.

then all reagents and tubes were renewed for next 7–10 days measurement. Blank, standard solutions and washing reagent were successfully substituted for sea water a six hours interval automatically with three electric valves controlled by five timers.

2.2. *Navigation data*

In No. 5 laboratory, there was an output terminal of ship's navigation data as shown in Fig. 4. Navigation data (GMT, position, ship's speed, sea depth, water and air temperature) were directly transferred from the terminal through a navigation interface to the CPU.

2.3. *Control unit*

A personal computer (YHP 9836 CS, USA) was used for a real time data processing as well as a post data processing. Data sampling was made every five minutes. Local mean time (LMT) was calculated from navigation data of GMT and longitude of

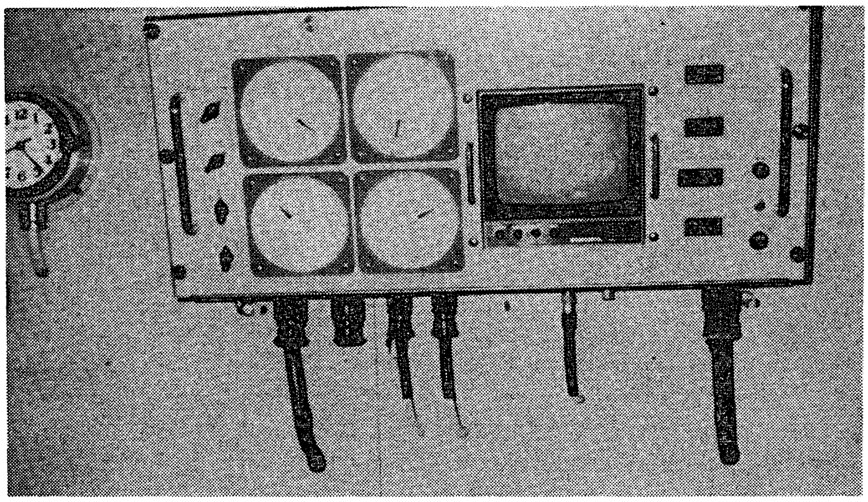

Fig. 4. Data output terminal of ship's navigation information.

ship's position. LMT is not equal to an ordinary ship's time, which sometimes does not synchronize with the actual solar rhythm.

Analog signals from seven kinds of sensors were transferred to the input/output port of the EPCS. At each data sampling time, averaged values for 60 s of seven sensors as well as navigation data were stored on a floppy disk, and concurrently printed out by a line printer (Epson, RP-100 II, Japan). Also, the time series data were displayed graphically on CRT of the computor. At every 0000 LMT, a time series graph of six kinds of data display on CRT was plotted out by an X-Y plotter (YHP 7475A, USA). The control unit is shown in Fig. 5.

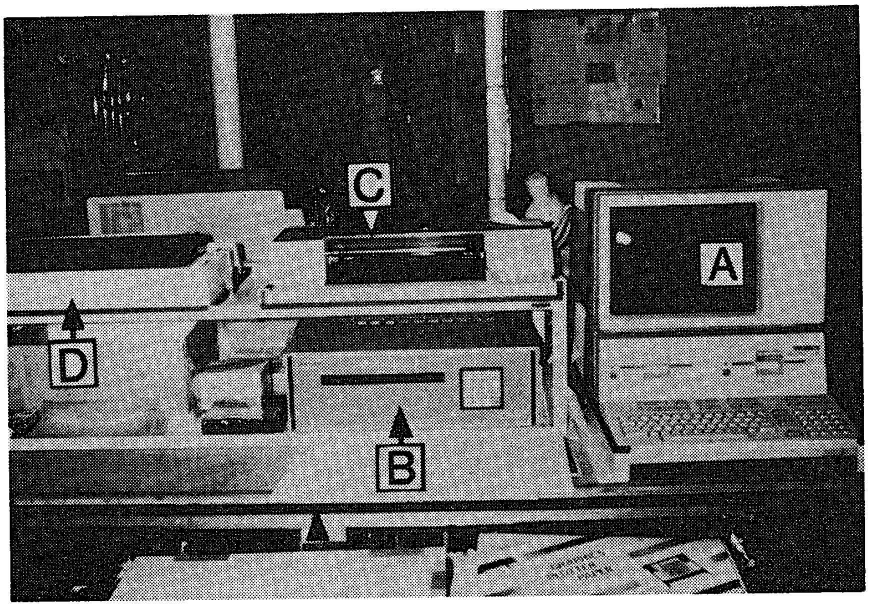

Fig. 5. System control unit. A: personal computer, B: interface of navigation data, C: plotter, and D: printer.

A post data processing firstly is applied for data editing as follows; to delete abnormal data, to correct data, to calibrate fluorescence intensity into chlorophyll *a* concentration (based on regression obtained from manual measurements of chlorophyll *a* of the same water sample), to calibrate colorimetric intensity into nutrient concentration, and to correct time lag of nutrient data. Edited data are also stored on a floppy disk. These edited data are then printed out as well as plotted in a time series graphic way and in a geographical distribution on a map.

3. Field Experiment in JARE-27 (1985/86)

The new surface water monitoring system was tested in Japan in detail. However, the calibration of plankton sensor was not completed until the icebreaker SHIRASE sailed for Antarctica on 14 November 1985.

In the study, among the data collected from the 5 months cruise, data of the southeast bound course from Fremantle, Western Australia, to Syowa Station located at 69°00′S, 39°35′E (3–12 December 1985), and of the north bound course to Port Louis, Mauritius (26 February–14 March 1986) are sorted out and edited. An example of

Table 2. An example of edited data obtained from a post data processing (omitted for plankton data).

GMT Date	GMT Time	LMT Date	LMT Time	Lat	Long	Depth [m]	Atemp [°C]	Wtemp [°C]	Speed [Kt]	Flow [l/m]	Wtemp [°C]	Sal [ppt]	Do [ml/l]	Chl [ug/l]	Nutr [ug-at/l]
85/12/07	04:00	12/07	10:40	50-43.3S	100-14.5	3617	6.5	6.8	12.0	17.46	6.92	34.07	3.13	.26	-25.44
85/12/07	04:05	12/07	10:45	50-44.0S	100-13.5	3548	6.5	6.6	11.0	17.42	6.89	33.94	3.12	.25	-24.85
85/12/07	04:10	12/07	10:50	50-44.8S	100-12.5	3805	6.5	6.7	11.2	17.40	6.85	33.97	3.11	.24	-24.98
85/12/07	04:15	12/07	10:55	50-45.5S	100-11.5	0	6.5	6.6	10.7	17.26	6.79	34.04	3.10	.23	22.08
85/12/07	04:20	12/07	11:00	50-46.2S	100-10.6	3734	6.5	6.4	11.0	17.22	6.74	33.93	3.10	.22	22.21
85/12/07	04:25	12/07	11:05	50-46.9S	100-09.6	3797	6.5	6.4	11.7	17.27	6.71	33.96	3.09	.20	22.34
85/12/07	04:30	12/07	11:10	50-47.6S	100-08.6	3657	6.5	6.3	11.7	17.42	6.67	34.00	3.09	.19	22.37
85/12/07	04:35	12/07	11:15	50-48.4S	100-07.6	3568	6.5	6.3	11.9	17.51	6.66	34.02	3.09	.18	22.27
85/12/07	04:40	12/07	11:20	50-49.1S	100-06.7	3680	6.4	6.3	10.8	17.26	6.66	34.02	3.08	.17	22.28
85/12/07	04:45	12/07	11:25	50-49.9S	100-05.6	3694	6.5	6.3	11.3	17.34	6.66	34.02	3.08	.16	22.30
85/12/07	04:50	12/07	11:30	50-50.6S	100-04.7	3607	6.3	6.4	12.0	17.32	6.66	34.02	3.08	.16	22.47
85/12/07	04:55	12/07	11:35	50-51.4S	100-03.6	3621	6.3	6.3	12.4	17.20	6.61	34.06	3.07	.16	22.71
85/12/07	05:00	12/07	11:40	50-52.1S	100-02.6	3576	6.3	6.2	12.6	17.04	6.55	33.96	3.05	.15	23.29
85/12/07	05:05	12/07	11:45	50-53.0S	100-01.5	3620	6.3	6.1	12.2	17.41	6.40	33.96	3.04	.17	23.44
85/12/07	05:10	12/07	11:50	50-53.8S	100-00.4	3493	6.3	6.1	13.1	17.36	6.32	34.04	3.03	.18	23.38
85/12/07	05:15	12/07	11:54	50-54.5S	099-59.5	3650	6.3	6.0	12.4	17.28	6.32	34.04	3.03	.17	23.51
85/12/07	05:20	12/07	11:59	50-55.3S	099-58.3	3581	6.3	6.1	13.2	17.29	6.28	33.92	3.03	.17	23.61
85/12/07	05:25	12/07	12:04	50-58.9S	099-58.9	3632	6.3	6.1	13.0	17.19	6.28	33.92	3.03	.16	23.61
85/12/07	05:30	12/07	12:09	50-59.8S	099-57.8	3743	6.3	6.1	12.5	17.26	6.27	33.93	3.02	.17	23.68
85/12/07	05:35	12/07	12:14	51-00.5S	099-56.7	3616	6.3	6.1	12.8	17.22	6.25	33.95	3.02	.16	23.78
85/12/07	05:40	12/07	12:19	51-01.8S	099-54.5	3767	6.3	6.1	13.3	17.32	6.29	34.07	3.01	.15	23.93
85/12/07	05:45	12/07	12:24	51-02.6S	099-53.5	3780	6.3	5.8	13.2	17.41	6.20	34.00	3.02	.15	24.25
85/12/07	05:50	12/07	12:29	51-03.4S	099-52.3	3735	6.3	5.6	13.3	17.46	5.95	33.94	3.01	.15	24.61
85/12/07	05:55	12/07	12:34	51-04.2S	099-51.2	3714	6.3	5.5	11.8	17.54	5.78	33.95	2.99	.15	24.90

edited data is listed in Table 2. Negative values in nutrient column indicate the data on blank and standard measurements (not on the sample data).

Geographical distributions of the surface chlorophyll *a* along the southeast bound and the north bound courses are plotted out as in Fig. 6.

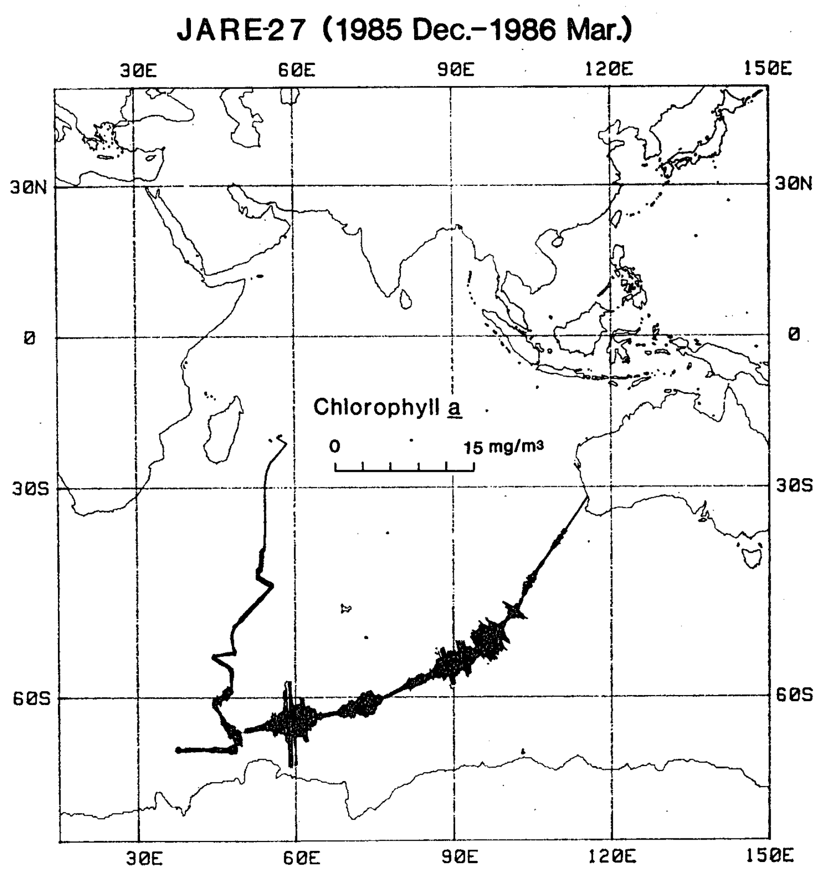

Fig. 6. Geographical graphic display on chlorophyll a concentration in JARE-27 between December 1985 and March 1986.

In the subantarctic and Antarctic areas along the southeast bound course, several peaks of high chlorophyll *a* concentration are clearly seen. These peaks are also reported from the preceding two cruises (TANIGUCHI *et al.*, 1986; FUKUCHI *et al.*, 1986). On the contrary, the chlorophyll *a* distribution along the north bound course is quite different. No distinct variation is detected from the north bound course.

An example of the time series data (except for plankton data) plotted out between 4 and 11 December 1986 along the southeast bound course is shown in Fig. 7. Temperature and salinity decreased from the subtropical water to the Antarctic water. On the other hand, nutrient (nitrate plus nitrite nitrogen) increased toward south, while the rapid change occurred at the oceanic frontal zones such as Subtropical Convergence, Subantarctic Front and Antarctic Convergence. Blank parts in the time series nutrient data coincides with the period of standard and blank measurements at 6 h intervals. Chlorophyll *a* fluctuated largely, showing several peaks.

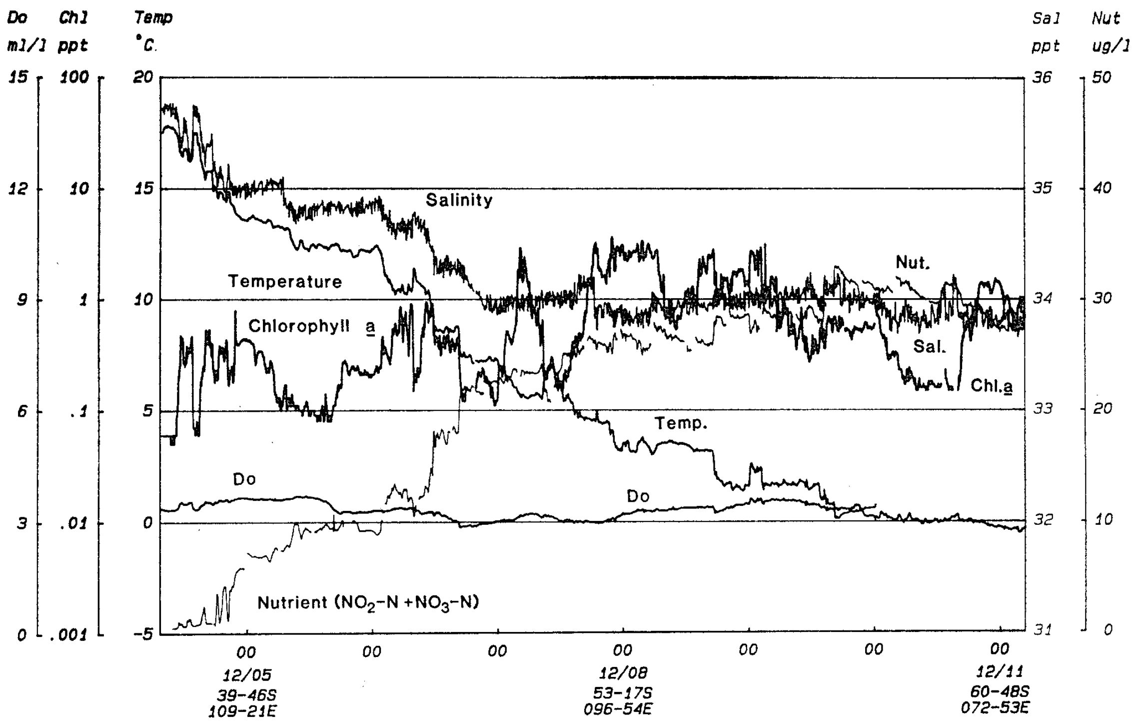

Fig. 7. Time series graphic display based on data sampled between 4 and 11 December 1985 along the southeast bound course of the icebreaker SHIRASE *(plankton data are omitted).*

4. Closing Remarks

The present system, which can be regarded as a so-called surface water monitoring system, is a useful tool not only to detect the oceanic frontal zone but also to analyze fine-micro scale plankton distribution, in particular, in relation to the environmental variables. The plankton sensor was calibrated for the following JARE-28 cruise in 1986/87 and interesting data were accumulated.

Acknowledgments

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